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(54) STEERING SYSTEM

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B62D 15/02 (2006.01)
B62D 5/04 (2006.01)

(52) **U.S. Cl.**
CPC ***B62D 15/021*** (2013.01); ***B62D 5/049*** (2013.01)

(58) **Field of Classification Search**
USPC 701/41, 44, 1
See application file for complete search history.

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(57) **ABSTRACT**

A steering system includes a rotation angle sensor that detects a signal related to an absolute steering angle, and an assist circuit that acquires the signal related to the absolute steering angle while an ignition switch is off in order to reduce battery consumption. The assist circuit includes a counter that updates a count value based on a result of detection by a first rotating direction determining unit and a second rotating direction determining unit that determine a rotating direction of a motor, and an abnormality detecting unit that detects an abnormality in absolute steering angle based on a past value and a current value of the count value in the counter.

8 Claims, 3 Drawing Sheets

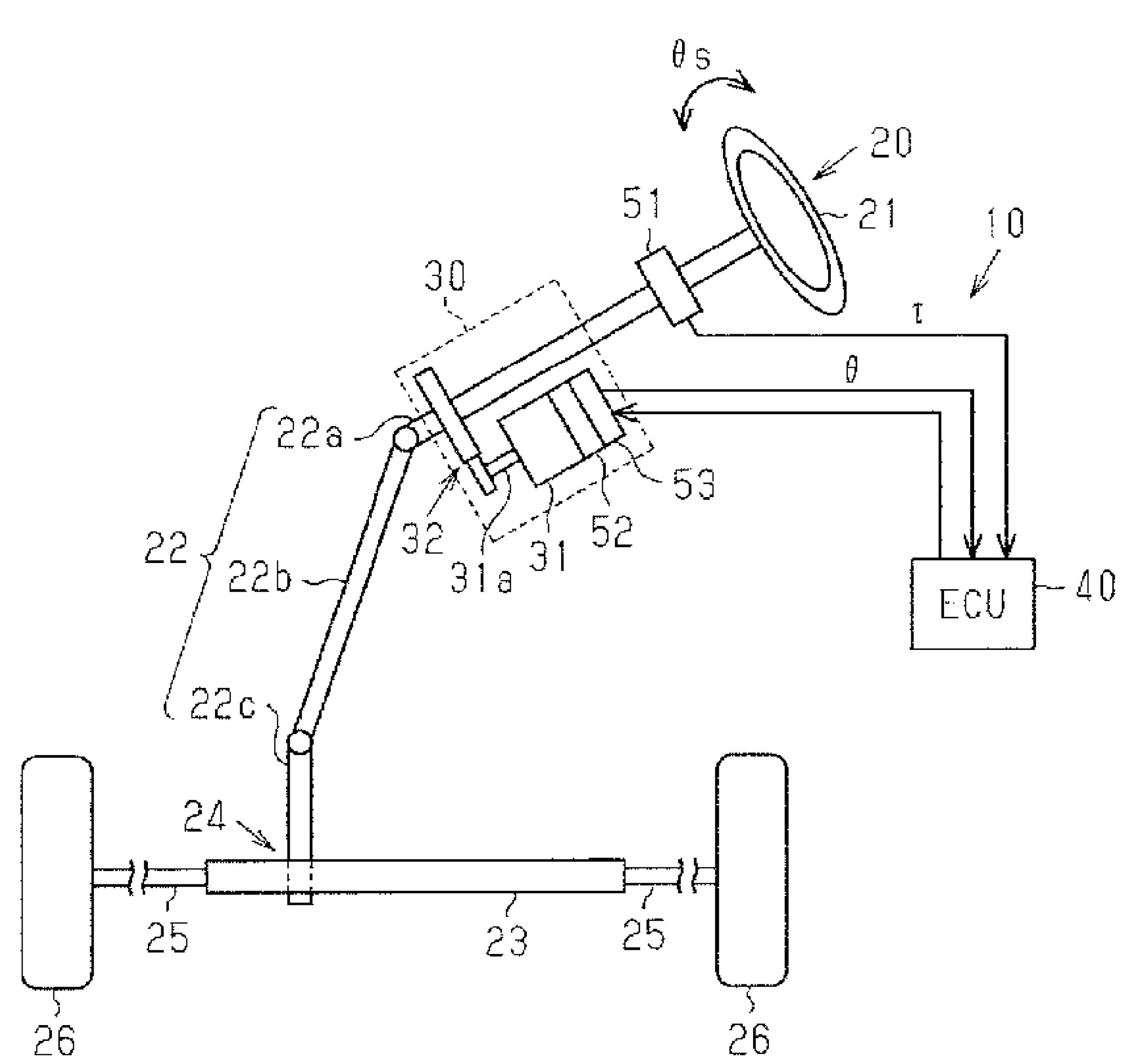


FIG.1

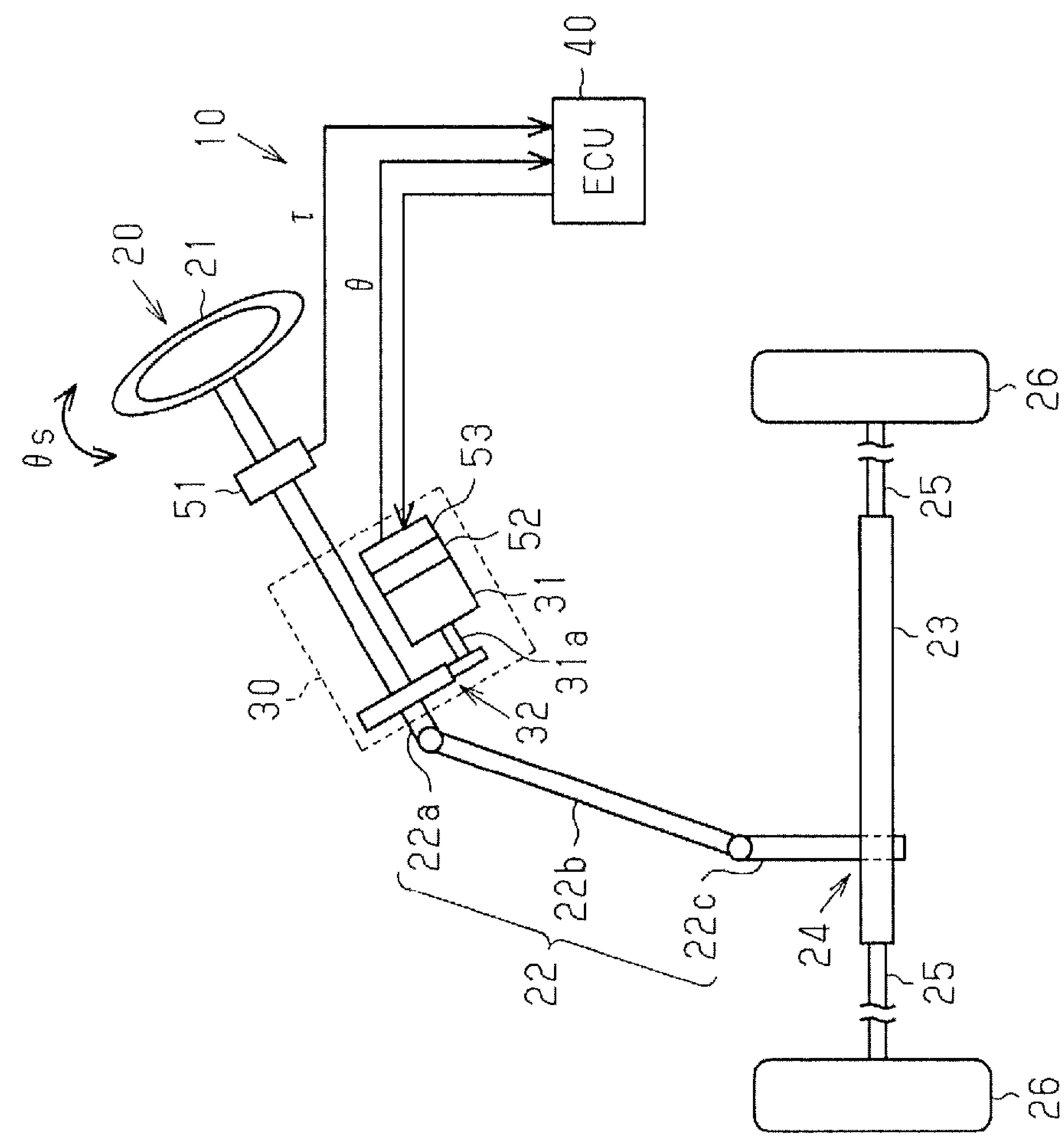


FIG.2

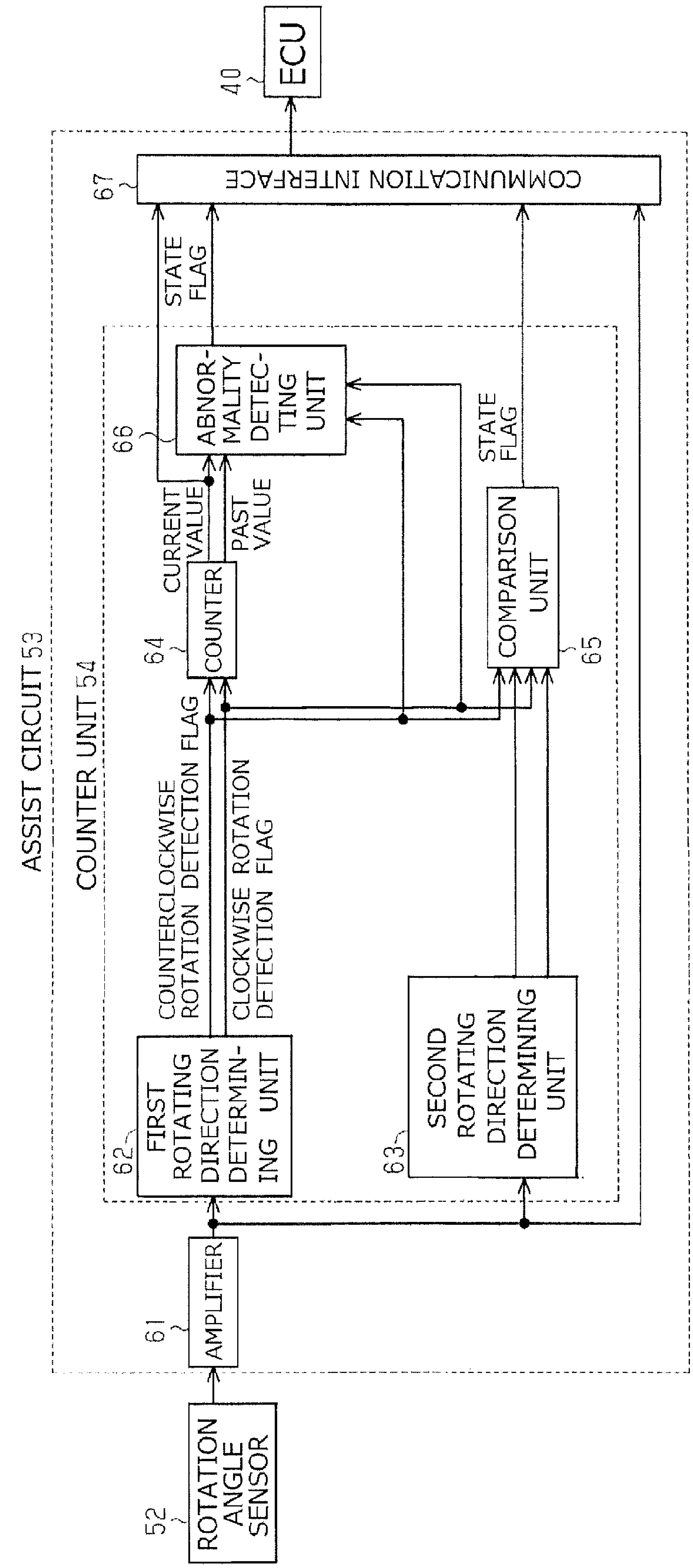
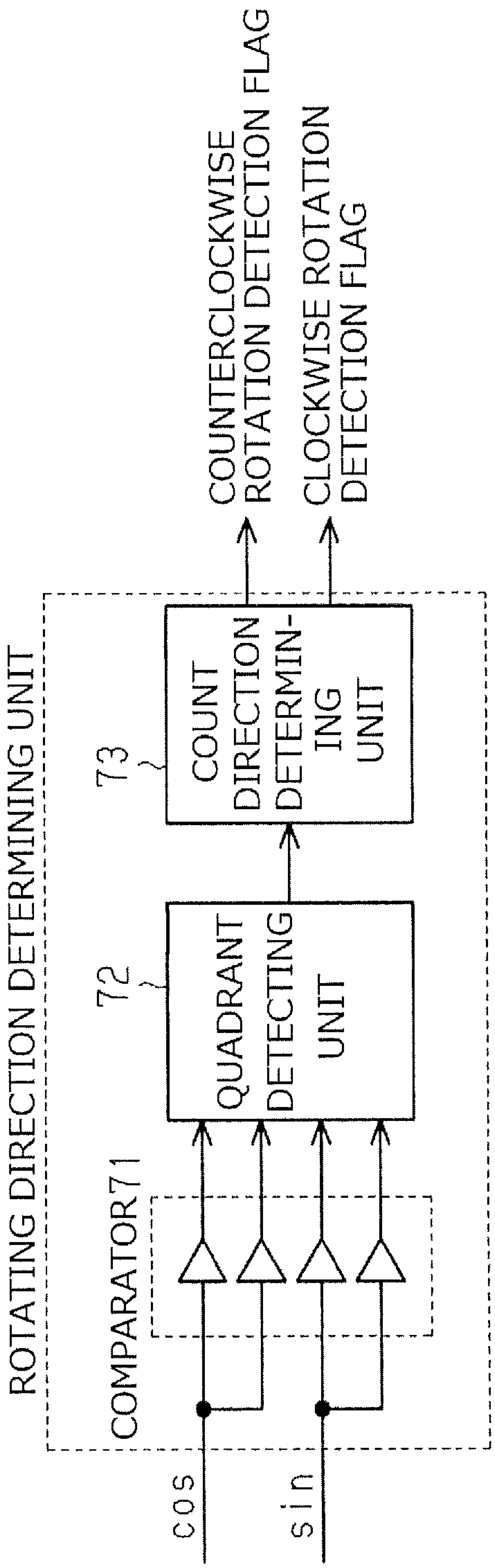

ECU
40
COMMUNICATION INTERFACE
67
STATE FLAG
ABNOR-MALITY DETEC-TING UNIT
66
STATE FLAG
CURRENT VALUE
PAST VALUE
COUNTER
64
COMPARISON UNIT
65
ASSIST CIRCUIT 53
COUNTER UNIT 54
COUNTERCLOCKWISE ROTATION DETECTION FLAG
CLOCKWISE ROTATION DETECTION FLAG
FIRST ROTATING DIRECTION DETERMIN-ING UNIT
62
SECOND ROTATING DIRECTION DETERMINING UNIT
63
AMPLIFIER
61
ROTATION ANGLE SENSOR
52

FIG.3


ROTATING DIRECTION DETERMINING UNIT
COMPARATOR71
72
QUADRANT DETECTING UNIT
73
COUNT DIRECTION DETERMIN-ING UNIT
COUNTERCLOCKWISE ROTATION DETECTION FLAG
CLOCKWISE ROTATION DETECTION FLAG
cos
sin

STEERING SYSTEM

INCORPORATION BY REFERENCE

The disclosure of Japanese Patent Application No. 2014-126972 filed on Jun. 20, 2014 including the specification, drawings and abstract, is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a steering system.

2. Description of Related Art

Vehicular systems include various systems such as a steering system, a brake system, a back guide system, and a vehicular stability control system which perform control using an absolute steering angle. For example, in a steering system described in European Patent No. 2050658, the absolute steering angle is detected using an evaluation unit configured as an ASIC including a sensor that can detect a relative steering angle and a counter that increases and decreases a count value in accordance with a relative steering angle signal obtained from the sensor even while an ignition switch is off (during an IG off state). That is, to what period the steering angle corresponds is determined based on the count value, and the absolute steering angle is evaluated using the relative steering angle detected by the sensor.

If an abnormality such as a mismatch between the relative steering angle signal and an increase or a decrease in count value occurs in the evaluation unit, an incorrect absolute steering angle may be detected. Detection of the incorrect absolute steering angle causes a controller for the steering system to perform control based on the incorrect absolute steering angle. Thus, the system in European Patent No. 2050658 detects an abnormality in absolute steering angle as follows. That is, two such counters as described above are provided to make a count function redundant so that an abnormality detecting unit can compare two count values to determine whether the detected absolute steering angle is normal. Upon determining the absolute steering angle to be abnormal, the controller for the steering system stops the control based on the absolute steering angle.

The steering system in European Patent No. 2050658 certainly enables an abnormality in absolute steering angle to be detected. However, the system needs processing time to compare the two count values. The time needed to determine an abnormality in absolute steering angle is also increased by an amount equal to the processing time.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a steering system that enables a reduction in time needed to determine an abnormality in steering angle.

A steering system according to an aspect of the present invention includes a position detector that detects a signal related to an absolute steering angle and an assist unit that acquires the signal related to the absolute steering angle while an ignition switch is off. The assist unit includes a counter that increases and decreases a count value based on a steering direction and an abnormality detecting unit that compares a past value and a current value of the count value to detect an abnormality in the absolute steering angle.

This configuration enables an abnormality in the absolute steering angle to be detected using the past value and the current value in the one counter. This is because the count value is a signal indicative of a change in the absolute steering angle. A configuration is possible in which a plurality of counters is provided to allow count values in the counters to be compared. However, compared to the configuration with the plurality of counters, the configuration according to the present aspect that detects an abnormality using a single counter enables a reduction in processing time for abnormality detection.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and further features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. **1** is a block diagram depicting a configuration of a steering system in an embodiment;

FIG. **2** is a schematic diagram depicting a configuration of an assist circuit in the embodiment; and

FIG. **3** is a schematic diagram of a rotating direction determining unit in the embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

An embodiment of a steering system will be described below. The steering system in the present embodiment is an electric power steering system (EPS) that applies an assist force to a steering mechanism using a motor.

As depicted in FIG. **1**, the EPS **10** includes a steering mechanism **20** that steers steered wheels **26** based on a driver's operation of a steering wheel **21**, a steering assist mechanism **30** that assists the driver's steering operation, and an electronic control unit (ECU) **40** that controls the steering assist mechanism **30**.

The steering mechanism **20** includes the steering wheel **21** and a steering shaft **22** that rotates integrally with the steering wheel **21**. The steering shaft **22** includes a column shaft **22***a* coupled to the steering wheel **21**, an intermediate shaft **22***b* coupled to a lower end of the column shaft **22***a*, and a pinion shaft **22***c* coupled to a lower end of the intermediate shaft **22***b*. A lower end of the pinion shaft **22***c* is coupled to a rack shaft **23** extending in a direction that crosses the pinion shaft **22***c*. Rotary motion of the steering shaft **22** is converted into axial reciprocating linear motion of the rack shaft **23** via a rack-and-pinion mechanism **24**. The reciprocating linear motion is transmitted to the right and left steered wheels **26** via tie rods **25** coupled to opposite ends of the rack shaft **23** to change the steered angles of the steered wheels **26**. Thus, a vehicle traveling direction is changed.

The steering assist mechanism **30** includes a motor **31** that is a source of a steering assist force. A rotating shaft **31***a* of the motor **31** is coupled to the column shaft **22***a* via a speed reduction mechanism **32**. The speed reduction mechanism **32** reduces the speed of rotation output from the motor **31** to transmit a torque generated by the motor **31** to the column shaft **22***a*. A steering torque τ of the motor **31** is applied to the steering shaft **22** as the steering assist force to assist the driver's steering operation.

The ECU **40** controls the motor **31** based on detection signals from various sensors provided in the vehicle. The various sensors include, for example, a torque sensor **51** and a rotation angle sensor **52**. The torque sensor **51** is provided on the column shaft **22***a*, and the rotation angle sensor **52** is attached to the motor **31**. The torque sensor **51** detects the steering torque τ applied to the steering shaft **22** as a result of the driver's steering operation. The rotation angle sensor **52** is provided on the motor **31** to output an electric signal according to the rotation angle θ of the rotating shaft **31***a*. The electric signal according to the rotation angle θ is a signal related to an absolute steering angle θs. For example, a magnetoresistive sensor (MR sensor) is adopted as the rotation angle sensor **52**. The MR sensor has a bridge circuit including a plurality of magnetoresistive elements. The rotation angle sensor **52** generates a sin signal and a cos signal as the electric signal according to the rotation angle θ. The ECU **40** controls the motor **31** based on the steering torque τ detected by the torque sensor **51** and the electric signal generated by the rotation angle sensor **52**.

The motor **31** is provided with an assist circuit **53**. The assist circuit **53** outputs the signal related to the absolute steering angle θs detected by the rotation angle sensor **52**, to the ECU **40**, to assist the ECU **40** in calculating the absolute steering angle θs. The assist circuit **53** may be configured as a single integrated circuit (ASIC). The signal related to the absolute steering angle θs obtained by the rotation angle sensor **52** while an ignition switch is off (during an IG off state) is recorded in the assist circuit **53**. While the ignition switch is on (during an IG on state), the assist circuit **53** outputs the signal related to the absolute steering angle θs and recorded in the assist circuit **53**, to the ECU **40** via an interface **67**. The ECU **40** executes calculation on the output from the rotation angle sensor **52** and the signal related to the absolute steering angle θs and output by the assist circuit **53**, to output the absolute steering angle θs. The ECU **40** then records the absolute steering angle θs immediately before IG is turned off. During the IG off state, the ECU **40** is stopped, so no change in the absolute steering angle θs can be detected. That is, when the IG is turned on with the absolute steering angle θs having changed during the IG off state, the ECU **40** may perform control with the incorrect absolute steering angle θs. Thus, the absolute steering angle θs needs to be monitored by the rotation angle sensor **52** and the assist circuit **53** even during the IG off state.

To allow the signal related to the absolute steering angle θs to be detected with a reduction in power consumption of a battery, power from the battery is supplied to the rotation angle sensor **52** during the IG off state. For a reduction in battery consumption, during the IG off state, no power is supplied to the ECU **40**, whereas power from the battery is supplied to the rotation angle sensor **52** and the assist circuit **53**. Power may be intermittently supplied to the rotation angle sensor **52**. The signal related to the absolute steering angle θs need not be constantly detected but may be detected at time intervals sufficient to determine whether the absolute steering angle θs has changed during the IG off state. The intermittent power supply enables a reduction in power consumption.

During the IG on state, the ECU **40** is supplied with power from the battery. The ECU **40** detects a rotation angle θ by calculating an arctangent value based on the sin signal and cos signal obtained by the rotation angle sensor **52**. The ECU **40** uses the rotation angle θ to calculate the absolute steering angle θs. Based on the relationship between the rotation angle θ and the absolute steering angle θs, the absolute steering angle θs can be calculated using the rotation angle θ. During the IG off state, the ECU **40** records the absolute steering angle θs obtained immediately before the IG is turned off.

Now, a configuration of the assist circuit **53** will be described.

As depicted in FIG. **2**, the assist circuit **53** has an amplifier **61**, a counter unit **54**, and a communication interface **67**.

The amplifier **61** amplifies the sin signal and cos signal generated by the rotation angle sensor **52**. For the assist circuit **53**, a configuration without the amplifier **61** may be adopted.

The counter unit **54** is a unit that performs counting based on the electric signal (sin signal and cos signal) generated by the rotation angle sensor **52** and generally has two functional sections. A first functional section detects the rotating direction of the motor **31** based on the rotation angle sensor **52** to update a count value according to the rotating direction of the motor **31** and the electric signal generated by the rotation angle sensor **52**. A second functional section detects the result of determination of the rotating direction by the first functional section and an abnormality in count value.

As depicted in FIG. **2**, the first functional section has a first rotating direction determining unit **62**, a second rotating direction determining unit **63**, and a counter **64**.

The first rotating direction determining unit **62** determines the rotating direction (clockwise rotation or counterclockwise rotation) of the motor **31** based on the sin signal and cos signal amplified by the amplifier **61**. Upon determining that the rotating direction of the motor **31** is counterclockwise, the first rotating direction determining unit **62** turns on a counterclockwise rotation detection flag indicating that the rotating direction of the motor **31** is counterclockwise. Upon determining that the rotating direction of the motor **31** is clockwise, the first rotating direction determining unit **62** turns on a clockwise rotation detection flag indicating that the rotating direction of the motor **31** is clockwise.

FIG. **3** is a schematic diagram of the rotating direction determining unit. The first rotating direction determining unit **62** and the second rotating direction determining unit **63** have the same configuration, and thus, the first rotating direction determining unit **62** will be described by way of example. The first rotating direction determining unit **62** includes a comparator **71**, a quadrant detecting unit **72**, and a count direction determining unit **73**.

The comparator **71** generates a Hi level signal when the signal level of the sin and cos signals generated by the rotation angle sensor **52** has a value larger than a set threshold, and generates a Lo level signal when the signal level has a value smaller than the set threshold.

The quadrant detecting unit **72** determines to which of four possible quadrants the phase of the rotation angle θ of the motor **31** currently corresponds, based on a combination of the Hi level signal and the Lo level signal generated by the comparator **71**. Specifically, the quadrant detecting unit **72** makes determination as follows.

(A1) When both the sin signal and the cos signal are at the Hi level. At this time, the rotation angle θ of the motor **31** is determined to correspond to a first quadrant.

(A2) When the sin signal is at the Hi level and the cos signal is at the Lo level. At this time, the rotation angle θ of the motor **31** is determined to correspond to a second quadrant.

(A3) When both the sin signal and the cos signal are at the Lo level. At this time, the rotation angle θ of the motor **31** is determined to correspond to a third quadrant.

(A4) When the sin signal is at the Lo level and the cos signal is at the Hi level. At this time, the rotation angle θ of the motor **31** is determined to correspond to a fourth quadrant.

The count direction determining unit **73** compares the current and last quadrants determined by the quadrant detecting unit **72**. The count direction determining unit **73** turns on a counterclockwise rotation detection flag or a clockwise rotation detection flag when the current quadrant is different from the last quadrant. When the quadrant changes counterclockwise, for example, from the first quadrant to the second quadrant, the counterclockwise rotation detection flag is turned on, and the clockwise rotation detection flag is off. When the quadrant changes clockwise, for example, from the first quadrant to the fourth quadrant, the counterclockwise rotation detection flag is off, and the clockwise rotation detection flag is turned on. When no change occurs in quadrant, both the counterclockwise rotation detection flag and the clockwise rotation detection flag are off. When the count direction determining unit **73** is normal, it is impossible that both the counterclockwise rotation detection flag and the clockwise rotation detection flag are turned on. If both the counterclockwise rotation detection flag and the clockwise rotation detection flag are turned on, a state flag indicative of an abnormality is turned on.

As described above, the first rotating direction determining unit **62** converts the electric signal (sin signal and cos signal) generated by the rotation angle sensor **52** into the counterclockwise rotation detection flag and the clockwise rotation detection flag for the motor **31**.

The counter **64** updates the count value based on the state flag for the first rotating direction determining unit **62**. That is, the counter **64** increments the count value (increases the count value by one) when the counterclockwise rotation detection flag is on and decrements the count value (decreases the count value by one) when the clockwise rotation detection flag is on. Since the counterclockwise rotation detection flag or the clockwise rotation detection flag is turned on when the quadrant changes, the count value is updated each time the rotation angle θ changes by 90 degrees.

As depicted in FIG. **2**, the second functional section has a comparison unit **65** and an abnormality detecting unit **66**.

The comparison unit **65** compares the state flag for the first rotating direction determining unit **62** with the state flag for the second rotating direction determining unit **63** to determine whether or not the state flags match. Specifically, the comparison unit **65** compares the counterclockwise rotation detection flag for the first rotating direction determining unit **62** with the counterclockwise rotation detection flag for the second rotating direction determining unit **63**. The comparison unit **65** also compares the clockwise rotation detection flag for the first rotating direction determining unit **62** with the clockwise rotation detection flag for the second rotating direction determining unit **63**. When the counterclockwise rotation detection flag for the first rotating direction determining unit **62** does not match the counterclockwise rotation detection flag for the second rotating direction determining unit **63**, the comparison unit **65** turns on a state flag indicative of the mismatch. When the clockwise rotation detection flag for the first rotating direction determining unit **62** does not match the clockwise rotation detection flag for the second rotating direction determining unit **63**, the comparison unit **65** turns on a state flag indicative of the mismatch.

The abnormality detecting unit **66** detects an abnormality in count value based on the count value (current value and last value) in the counter **64** and the state flags (counterclockwise rotation detection flags and clockwise rotation detection flags) for the first rotating direction determining unit **62** and the second rotating direction determining unit **63**. When no abnormality is detected, the abnormality detecting unit **66** outputs the current value to the ECU **40** when the IG is turned on, as assistance data for calculation of the absolute steering angle θs. That is, the ECU **40** calculates the first absolute steering angle θs after the IG is turned on, taking into account the absolute steering angle θs recorded in the ECU **40** immediately before the IG is turned off, the rotation angle θ obtained from the rotation angle sensor **52** during the IG on state, and the amount of change in steering angle derived from the count value.

The abnormality detecting unit **66** detects an abnormality in the following four cases. Upon detecting an abnormality, the abnormality detecting unit **66** turns on a state flag indicative of the abnormality.

(B1) When the counterclockwise rotation detection flag is on, the clockwise rotation detection flag is off, a numerical difference is present between the current value and last value of the count value, and the current value is larger than the last value.

(B2) When the counterclockwise rotation detection flag is off, the clockwise rotation detection flag is on, a difference is present between the current value and last value of the count value, and the current value is smaller than the last value.

(B3) When the counterclockwise rotation detection flag is off, the clockwise rotation detection flag is off, and the current value and the last value do not match.

(B4) When the counterclockwise rotation detection flag is on and the clockwise rotation detection flag is on.

The communication interface **67** transmits signals for the count value, the state flag, and the rotation angle θ of the motor **31** output by the rotation angle sensor **52**, to the ECU **40** while the IG is on.

The ECU **40** is active only during the IG on state. This is to suppress the power consumption of the battery during the IG off state. During the IG on state, the ECU **40** retrieves various signals, that is, signals related to the count value, the state flag, and the absolute steering angle θs output by the rotation angle sensor **52**. However, the assist circuit **53** need not always operate during the IG on state, and it is also preferable that the count value, the state flag, and the like obtained from the assist circuit **53** are obtained only immediately after the IG is turned on.

During the IG on state, power is supplied to all of the components such as the rotation angle sensor **52**, the assist circuit **53**, and the ECU **40**. However, the assist circuit **53** need not constantly be supplied with power during the IG on state. Thus, first, the rotation angle sensor **52** is supplied with power to output an electric signal corresponding to the rotation angle θ of the motor **31**. In accordance with the output from the rotation angle sensor **52**, the counter unit **54** outputs the rotating direction of the motor **31**, the count value, and the state flag. The output from the rotation angle sensor **52** and the output from the counter unit **54** are transmitted to the ECU **40** via the communication interface **67** during the IG on state. The ECU **40** calculates the absolute steering angle θs from these outputs.

During the IG off state, only some of the components are supplied with power. That is, power is supplied to the rotation angle sensor **52**, the amplifier **61**, the first rotating direction determining unit **62**, the second rotating direction determining unit **63**, and the counter **64**. No power is supplied to the ECU **40** or the communication interface **67**. Thus, the electric signal output by the rotation angle sensor **52** and corresponding to the rotation angle θ of the motor **31** is recorded in the counter **64** as the current value and the last value of the count value. Thus, the electric signal is not transmitted to the ECU **40** during the IG off state.

Now, operations of the EPS **10** will be described.

Normally, while the IG is on, the ECU **40** calculates the rotation angle θ of the motor **31** based on the electric signal (sin signal and cos signal) generated by the rotation angle sensor **52** and calculates the absolute steering angle θs using the rotation angle θ. The ECU **40** calculates a needed assist force based on the steering torque τ and the absolute steering angle θs, and controls the power supply to the motor **31** to allow the assist force to be applied to the steering mechanism **20**.

When the IG is turned off, the counter **64** updates the count value depending on the rotating direction of the motor **31** determined by the first rotating direction determining unit **62** even during the IG off state. Thus, even if the absolute steering angle θs changes during the IG off state due to the driver's movement of the steering wheel **21** or the like, the change is monitored.

When the IG, which has been off, is turned on, if the comparison unit **65** finds a mismatch in the rotating direction and the state flag indicative of an abnormality is detected, the correct value for the absolute steering angle θs fails to be detected until a normal state flag is detected. Thus, the use of the EPS **10** utilizing the absolute steering angle θs is stopped. This is because malfunction may occur when the EPS **10** uses the absolute steering angle θs while the absolute steering angle θs is unknown, for example, while it is unknown whether the absolute steering angle θs is zero degree or 360 degrees. When the normal state flag is detected during the IG on state, the ECU **40** calculates the correct value for the absolute steering angle θs using the absolute steering angle θs obtained immediately before the IG is turned off, the rotation angle θ obtained from the rotation angle sensor **52** and the count value. The ECU **40** then utilizes the absolute steering angle θs to control the apparatus.

The above-described steering system can provides advantageous effects described below.

(1) The last value and the current value in the counter **64** are compared to reduce the time needed for the abnormality detecting process. A method is available in which two counters **64** are provided to allow count values in these counters to be compared to detect an abnormality. However, the use of a single counter **64** for comparison of the last value and the current value enables a further reduction in the processing time needed to detect an abnormality. That is, if the count values in the two counters **64** are compared, data are collected from the two counters **64** and checked for a match, leading to the need for time to collect double the amount of data. In contrast, when the last value and the current value in the counter **64** are compared, data may be collected from the counter **64**, eliminating the need to collect double the amount of data. As a result, the method of using the single counter **64** to compare the last value with the current value enables a further reduction in the processing time needed to detect an abnormality compared to the method of using the two counters **64**. Furthermore, compared to the use of the two counters **64** for comparison, the use of the single counter **64** enables simplification of the configuration in the assist circuit **53** and reduction of the number of members of the system. Manufacturing costs are expected to be further reduced.

(2) During the IG off state, no power is supplied to the ECU **40**, and the rotating direction of the motor **31**, the count value, and the state flag are recorded by the counter unit **54**. This allows battery consumption to be suppressed. During the IG on state, power is supplied to the ECU **40**, and the ECU **40** calculates the absolute steering angle θs from the count value obtained by the counter unit **54** during the IG off state and the electric signal (sin signal and cos signal) generated by the rotation angle sensor **52**. With the battery consumption during the IG off state suppressed, a change in absolute steering angle θs can be monitored which results from the driver's operation of the steering wheel **21** during the IG off state.

(3) The first rotating direction determining unit **62** and the second rotating direction determining unit **63** allow the rotating direction of a steering shaft to be determined. Then, abnormality detection can be performed using the rotating direction of the steering shaft and the past value and current value in the counter **64**. Furthermore, a plurality of first rotating direction determining units **62**, a plurality of second rotating direction determining units **63**, and a plurality of comparison units **65** may be provided to detect an abnormality, allowing the reliability of the determined absolute steering angle to be improved.

(4) Abnormality detection is performed using the current value and the last value, which is the nearest past value, to allow an abnormality to be detected in the latest state with time lag further reduced.

(5) Intermittent power supply to the rotation angle sensor **52** and the assist circuit **53** enables a further reduction in battery consumption compared to constant power supply.

The above-described embodiment may be changed as follows. Other embodiments described below may be combined together to the extent that no technical contradiction occurs.

- In the present example, the present invention is implemented as the electric power steering system. However, a hydraulic power steering system or a steer-by-wire steering system may be implemented. Furthermore, the absolute steering angle θs calculated by the ECU **40** may be shared with other in-vehicle systems such as a brake, a back guide system, and a vehicular stability control system that use the absolute steering angle. The present example is also applicable to normal steering systems that do not assist the steering operation. In this case, control for assisting the steering operation is not performed, and thus, the ECU **40** for steering need not necessarily be provided. With the rotation angle sensor **52** and the assist circuit **53** unchanged, the calculation of the absolute steering angle θs may be executed by a controller for an in-vehicle system other than the steering system.
- In the present example, a change in the rotation angle θ of the rotating shaft **31***a* of the motor **31** is detected by the rotation angle sensor **52** to allow the absolute steering angle θs to be calculated. However, the rotation angle of the steering shaft **22** may be detected by the rotation angle sensor **52**.
- In the present example, the rotation angle sensor **52** that detects the rotation angle θ of the rotating shaft **31***a* of the motor **31** is used as a position detector that outputs a signal related to the absolute steering angle θs. However, a potentiometer that detects the amount of axial movement of the rack shaft **23** may be adopted.
- In the present example, the MR sensor is used as the rotation angle sensor **52**. However, a Hall sensor may be used. Alternatively, for example, a magnetic impedance element, a Faraday element, or a superconducting quantum interference device (SQUID) may be used. Besides the magnetic sensor, an ultrasonic sensor or an encoder may be adopted as the rotation angle sensor **52**.
- In the present example, the rotation angle sensor **52** serving as a position detector is provided on the column shaft **22***a*. However, the rotation angle sensor **52** may be provided on any portion of the steering shaft **22**. When the amount of axial movement of the rack shaft

23 is used as a signal related to the absolute steering angle θs, the potentiometer serving as a position detector that detects the amount of axial movement of the rack shaft **23** may be provided on the rack shaft **23**.

In the present example, the last value and the current value of the count value are compared to detect an abnormality in the counter **64**. However, the current value may be compared with a value at another past point in time. For example, the last but one value may be used for the comparison when the absolute steering angle θs is known to be unchanged. Alternatively, the last but one value, the last value, and the current value may be compared with one another or comparison may be performed on time series changes since any point in time as needed. For example, if, due to the intermittent power supply to the rotation angle sensor **52**, the abnormality detecting unit **66** need not frequently compare the current value with the past value, that is, may perform one comparison for every several count values, the current value may be compared with the last but one value.

In the present example, the assist circuit **53** may be constantly supplied with power during the IG on state. That is, the assist circuit **53** is constantly supplied with power even during the IG on state to allow the count value to be updated. Thus, the ECU **40** need not record the absolute steering angle θs obtained immediately before the IG is turned off. The ECU **40** calculates the absolute steering angle θs using the count value and the rotation angle θ obtained from the rotation angle sensor **52** during the IG on state.

In the present example, the first rotating direction determining unit **62** and the second rotating direction determining unit **63** are provided as the circuit configuration. However, a mechanical configuration may be provided which performs counting in conjunction with the motion of gears or the like. For example, a configuration may be provided in which a gear is attached to the motor **31** so that, when the gear rotates in conjunction with the motor **31**, a mechanical counter **64** attached to the gear is used to perform automatic counting. That is, the mechanical counter **64** may be configured to mechanically increase the count value as the gear rotates and teeth of the gear move. In contrast, when the motor **31** rotates in the opposite direction, the count value mechanically decreases. Such a configuration eliminates the need for the first rotating direction determining unit **62** and the second rotating direction determining unit **63**.

In the present example, the first rotating direction determining unit **62** and the second rotating direction determining unit **63** are provided. However, the first rotating direction determining unit **62** and the second rotating direction determining unit **63** may be omitted. For example, it is sufficient to be able to determine whether or not the motor **31** has rotated, with the rotating direction of the motor **31** not determined. Given that a rotation flag is turned on when the motor **31** has rotated and is off when the motor **31** has not rotated, the abnormality detecting unit **66** detects an abnormality in the following two cases.

(C1) When the rotation flag is off and a specified numeral difference is present between the current value and the past value of the count value.

(C2) When the rotation flag is on and the specified numeral difference is not present between the current value and the past value of the count value.

In the present example, the second rotating direction determining unit **63** and the comparison unit **65** are provided. However, the second rotating direction determining unit **63** and the comparison unit **65** need not necessarily be provided. In that case, it is impossible that the comparison unit **65** determines an abnormality in the first rotating direction determining unit **62** and the second rotating direction determining unit **63**, but the abnormality detecting unit **66** can detect an abnormality in the count value in the counter **64**. On the contrary, three or more second rotating direction determining units **63** may be provided. In that case, the comparison unit **65** using the second rotating direction determining units **63** detects an abnormality in each of the second rotating direction determining units **63**.

What is claimed is:

1. A steering system comprising:

a position detector that is configured to detect a signal related to an absolute steering angle;

an assist unit that is configured to acquire the signal related to the absolute steering angle while an ignition switch is off;

a steering operation shaft that is configured to make linear motion in conjunction with rotation of a steering shaft to steer steered wheels; and

a motor that is configured to apply an assist force to the steering shaft or the steering operation shaft,

wherein the assist unit includes:

a counter that is configured to increase and decrease a count value based on a steering direction when the ignition switch is off; and

an abnormality detecting unit that is configured to compare the count value obtained when the ignition switch is off and a count value obtained immediately before the ignition switch is turned off to detect an abnormality in the absolute steering angle.

2. The steering system according to claim **1**, wherein

the assist unit includes a rotating direction determining unit that is configured to determine a rotating direction as the steering direction based on the acquired signal,

the counter is configured to update the count value based on the rotating direction determined by the rotating direction determining unit, and

the abnormality detecting unit is configured to detect an abnormality in the absolute steering angle based on the rotating direction of the steering shaft determined by the rotating direction determining unit and a result of comparison between the past value and the current value.

3. The steering system according to claim **2**, wherein

the assist unit includes a comparison unit and a plurality of the rotating direction determining units, and

the comparison unit is configured to compare the rotating directions determined by the rotating direction determining units to detect an abnormality in a determination result for the rotating direction.

4. The steering system according to claim **1**, wherein

the position detector is configured to generate, as the signal related to the absolute steering angle, an electric signal according to an amount of rotation of the motor.

5. The steering system according to claim **1**,

wherein the steering operation shaft is configured to make linear motion in conjunction with rotation of the steering shaft to steer the steered wheels, wherein

the position detector is configured to generate, as the signal related to the absolute steering angle, an electric signal according to an amount of rotation of the steering shaft or an amount of displacement of the steering operation shaft.

6. The steering system according to claim **4**, further comprising:

a controller that is configured to control the motor based on a signal related at least to a steering torque and the steering angle, wherein

while the ignition switch is off, power supply to the controller is stopped but power is continuously supplied to the position detector and the assist unit.

7. The steering system according to claim **1**, wherein the steering system is configured to intermittently drive the position detector and the assist unit.

8. The steering system according to claim **6**, wherein the signal related to a steering torque is detected by a torque sensor.

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